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## CONSTRUCTION OF T'IEN-SHUI--LAN-CHOU LINK OF LUNG-HAI RAILWAY, 1952

[Comment: This report on the construction of the T'ien-shui--Lan-chou link of the Lung-Hai Railway presents information from an article by Hsiu Wen, published in the October 1952 issue of the monthly periodical Kung-ch'eng Chien-she (Engineering Construction). It also lists graphics material on the same line, published in the September 1952 issue of Jen-min Hua-pao (People's Pictorial).

A summary of the article by Hsiu follows:]

The T'ien-shui-Lan-chou line is the last link in the Lung-Hai Railway which connects China's great Northwest with the central portion of the country. The Northwest has valuable power, agricultural, and mineral resources which are essential to the country's industrial development. The extension of the line into Sinkiang, will help to bring China and the Soviet Union closer together in politics and economics. Hence the urgency for the construction of this line.

A. Route of Line

Starting at T'ien-shui, the line follows the banks of the Wei Ho, past Kan-ku, Wu-shan, and Lung-hsi, for a distance of 150 kilometers. Beyond Lung-hsi, it proceeds in a northwesterly direction through Ting-hsi and Yu-chung to Lan-chou. The total length is 350 kilometers. When the main line is finished, a branch line will be built to Lin-t'ao, since the valley of the T'ao Ho is a rich area. Originally the people of Lin-t'ao pressed hard for the T'ien-Lan line to pass through Lin-t'ao, but technical reasons made it impossible.



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Among the serious natural obstacles encountered on the route between T'ien-shui and Lan-chou were three mountain gorges (1) a gorge beginning 44 kilometers west of T'ien-shui, where the terrain presented difficulties similar to those at some points on the Pao-chi--T'ien-shui line; (2) the Yuan-yang gorge, 4-5 kilometers long, lying not far west of Wu-shan; (3) the gorge of the Yellow River, 10-kilometers long, between Hsiang-hsia-tzu and Tung-kang-chen. A number of large bridges were required to span the valleys between the two ridges at elevations more than 1,000 meters higher than the elevation of T'ien-shui. Two long tunnels were required, one several hundred meters long [at Ch'u-erh-ch'a], and one 2 kilometers long [at Ta-ying-liang 1,900 meters]. To gain the necessary elevation, the alignment at one section has bends and reversed curves similar in form to the filament in an electric bulb, the track passing over itself at a higher level. For 150 kilometers, the line passes across an area practically destitute of water; and what water there is, is neither potable nor fit for locomotive boilers. Several tens of high bridges cross deep gullies in the loess soil region. Deposits of detritus and boulders along the banks of the river courses were encountered at many points.

B. Revised Standards

Standards on the line were revised as follows:

Least radius of curvature: R equals 300 meters, equivalent to D equals 3 degrees 49 minutes.

Maximum Gradient: 12 to 1,000 (including the curve reduction ratio).

Length of Transition or easement Curves: Originally set at 50 meters. To conform more closely to the standard set by the Ministry of Railways, this was lengthened to 60 meters. The maximum elevation of the outer rail on a curve, represented by "E," was 125 millimeters. This was fairly close to the Ministry's figure of 150 millimeters for "E" and 150 meters for "L" (length).

Distance Between Stations: On the average, the original distances were too great and were purely arbitrary. It was decided that a standard train should be able to cover the distance between two adjacent stations, in either direction in 36 minutes; or allowing for unusual circumstances, in 38 minutes. This would mean that the rational distance between two consecutive stations would be 7 - 8 kilometers. Hence it was decided to locate flag stations, where trains could pass each other, halfway between two regular stations.

Distance Between Water Towers This was set at distances requiring not more than 60 minutes running time, in either direction, between one water tower and another tower.

Minor Modifications Adopted:

1. On curves, the elevation of the outer rail and the widening of the distance between rails should commence at the beginning of the transition curve and gradually increase to its end.

2. Preferably, railway stations should be located on stretches of level straight track. But on this line, it was difficult to meet this requirement in all cases. Consequently, it was decided to permit, where necessary, the location of stations on curves having a minimum radius of curvature of 600 meters, or on gradients of from 0.5 to 0.7 percent. Entering and departing tracks should have an effective length of 650 meters. In a station yard the center-to-center distance between tracks should be 5 meters for the main tracks.

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3. The width of the crushed stone roadbed should be 5 meters. The elevation of the roadbed should be one meter above the level land on either side, and not less than 1/2 meter above the high water mark.

4. Vertical curves: Where the gradient change is more than 0.5 percent, the upward concave should be twice as long as the upward convex. Where the gradient change is 1.2 percent, the upward convex should be 240 meters long, and the upward concave should be 480 meters long.

5. Bridge loads: The construction of all bridge piers and abutments for permanent structures should conform to Chung-hua Schedule No 26. The superstructures, for the time being, may be constructed in accordance with Schedule No 20, since the latter is sufficient for presently anticipated traffic, and they may be replaced by stronger superstructures in the future if and when the traffic justifies or requires them.

6. Tunnels: For good ventilation and drainage, the gradients in tunnels should be 2 ? to 2 ? percent. This must be lessened at the ends and in the middle for tunnels over 300 meters long. Tunnels under [probably should read "over"] 600 meters long must be provided with a ventilation shaft. Tunnels over 1,000 meters long must have facilities for mechanically forced ventilation.

C. Labor Force

The rapid progress of this project was due to the use of army troops who were organized, had a high level of political consciousness, and were readily mobile in large numbers. They were highly effective on large-scale grading tasks such as deep cuttings. Compared with them, civilian peasant labor was not economical, since their work was constantly being interrupted by the agricultural tasks of the changing seasons. Good results were achieved when local government agencies let contracts to rural groups for excavating water cisterns. The major part of the work of a technical nature was done by regular teams of trained road construction workers equipped with machinery, such as bridge gangs, units of the army railway corps, and of the first section of the Engineering Bureau. Although some jobs were let out to commercial contractors, it was constantly necessary to guard against their exploitation of the peasant laborers.

D. Technical Problems

There was an area 150 kilometers long, extending from west of Lung-hsi and as far as Kan-ts'ao-tien, where the water was scarce, muddy, salty, and bitter. In two other areas, the water was only a little less objectionable. At great effort, sweet water was found at several points, such as that near Ma-ho-chen, at Kuan-men-k'ou, and at the Kan Ho near T'ang-chia-pao, but these sources of good water were negligible in quantity.

At a point 150 kilometers from Lung-hsi, two samples of water were secured and sent to Peiping for analysis. In every 1,000 grams of the sample water, there were 72 grams and 14.2 grams, respectively, of mud and sand. After evaporation, there was a residue of 6.7 grams and 7 grams, respectively. This residue was found to contain: $NaNO_3$, $Ca(NO_3)_2$, $NH_4Cl$, $NaCl$, $CaSO_4$, $NaHCO_3$, $Na_2CO_3$, $CaCO_3$, and traces of iron, magnesium and aluminum. For every metric ton of water, there were 7 kilograms of scale. On the scale of hardness, one sample was 84.8 and the other 132. Permanent hardness was 31.3 and 121.9, respectively. This water was more salty than sea water. Where such water was thrown on the ground and evaporated, it left a crust like hoarfrost. This water would not support grass or trees, and neither agricultural products nor farmers were found in those localities.



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In general, a locomotive running on a straight level track requires from 0.2 to 0.25 metric tons of water for every kilometer of distance. If this bad water were used, then everyday the boiler would accumulate from 210 to 250 quantities of scale, which would soon cause the locomotives to explode.

1. Locomotive Water Supply

There are three places where the water supply problem was most acute, namely, at Yao-yao (104 40, 35 25) [possibly another name for Hung-t'u-yao], Ting-hsi (104 26, 35 35), and Ch'eng-kou-i (104 16, 35 44); and two other places where it was only a little less acute. At each of these stations, the daily requirement of good water was from 1,000 to 2,000 [sic] metric tons. This was supplied by using a train to bring in good water from elsewhere, even though this was very expensive. To lay pipes for bringing in the water would be even more expensive, since it was difficult, if not impossible, to get the pumps and motive power, and maintenance would be a continuous expense. An attempt was made to drive a well at Ch'eng-kou-i; but no water was found even at a depth of 96 meters, and later, geologists said the layer of loess soil at that point was 600 meters thick.

2. Construction Work Water Supply

Cisterns: The local people all use cistern water. These cisterns are similar to dry wells, shaped like a huge water jar, and have capacity of approximately 45 cubic meters. After excavation, they are made water tight by applying several layers of waterproofing material. In the rainy season, everybody cooperates in collecting rain water until the cisterns are filled. The number of cisterns must be sufficient to meet the local needs until the next rainy season. The daily consumption of water per individual laborer was limited to 5 or 6 kilograms. Thus, each cistern could supply water for 2,000 to 2,500 man-days of labor. To accomplish the amount of necessary work on the railway in those areas which were dependent upon cistern water, it was found that 11,000 cisterns were required.

Artesian wells. Water from these wells was used when it was obtainable in the vicinity where bridge and culvert work was being done. When not otherwise obtainable, water was brought in by train

3. Landslides.

To avoid landslides or the collapse of the side walls in deep cuttings, it was found advisable to cut away more material at the top so that the side slopes were less steep, and the surfaces left smooth. The practice adopted on this line was that the slope should not be steeper than as follows: (1) for solid rock, 1/10 : 1, (2) for loose rock, 1/2 : 1, and (3) for firm earth, 3/4 : 1. When the nature of the excavated material was uniform, it was easy to assign a proper slope to prevent landslides; but when it varied, e.g., boulders in soil penetrated by water, then special precautionary measures had to be taken.

Methods used to prevent landslides were as follows:

a. Dig channels or ditches to divert water from the side walls.

b. Place sod or plant grass or other cover on slopes to protect against erosion.

c. Build barriers, with or without support of stakes, at a number of levels on a slope to intercept the accumulation of eroded material which might induce a large landslide.

d. Lay stone facing to cover the surface of the slope. Where two or more layers of rock are interspersed with soft material that is likely to give way under pressure, rake out the soft material and fill up the space with concrete or with stone grouted with cement.

e. Build a succession of stone arches on the surface of the slope with open paved gutters to take away surface water without erosion or absorption.

f. Build retaining walls. However, large retaining walls are quite expensive.

g. Where the amount of excavation required to secure proper side slopes in a deep cut would be very great due to the instability of the material, a minimum of excavation was made; that is, the side slopes were left very steep; than retaining walls of suitable height were built and bridged over with a concrete arched roof. Earth was then filled in on top, properly graded and drained. This roof formed a tunnel and no disturbance to traffic is anticipated at this point should any landslides occur subsequently.

h. In a narrow river valley, if it was practicable to do so, the alignment of the track was shifted near the edge of the river, thus reducing the amount of excavation and consequent probability of landslides. The comparative advantages and disadvantages of this course had to be carefully considered and balanced before deciding the best way to meet a given situation.

i. Where other means to avert landslides were impractic ble, an ordinary tunnel had to be made.

j. There were places where, in the rainy season, loose earth, sand, and gravel, brought down by water, were apt to flow and bury the track, or obstruct culverts. In such cases, an open-cut tunnel was built, or a bridge constructed instead of a culvert.

4. Deposits of Detritus

Extensive deposits of detritus were frequently encountered during the construction of this line. Even under ordinary conditions the drainage of such areas is a problem, but the torrents of the rainy seasons will seriously threaten the tracks laid across such deposits. Therefore, the practice has been to avoid such places as far as possible. If impossible, the plan used was to raise the grade and cross at a higher level; although this was not an ideal course to follow. The next best plan was to build a number of small bridges; in this case, the accumulation of sand and gravel or silt in the passages below the bridges must be dug away frequently to keep them unobstructed and lessen the hazard of extensive damage.

5. Broad, Shallow, Sandy River Beds

During most of the year, broad, shallow, sandy rivers have almost no water in them and are easily forded. After rains, the stream may suddenly increase to as much as 5 meters deep and 100 meters wide. When the current is rapid it scours its bed, and if slow, it deposits large quantities of sand, gravel and silt. The methods used to cope with these conditions are:

a. Bridge the river bed, keeping the bridge spans above the reach of the current. This often entails uneconomical grade changes.

b. Excavate below a low bridge. This may prove to be an endless and costly task.

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c. Build parallel embankments to channel the water in a way to ensure rapid drainage.

d. Tunnel under the river. In such a case, the entrances must be thoroughly safeguarded.

6. The Wei Ho Bridges

When the Pao-chi--T'ien-shui rail line was originally built [under the KMT regime], for the sake of economy, every effort was made to avoid crossing the Wei Ho, and no bridges were built to cross it. But because the cuts were deep and the slopes steep, the vibration caused by passing trains induced frequent collapse of the side walls. Thus, the line was not operable and had to be reconstructed. When we reconstructed it, many engineering changes had to be made. When the Tien-shui--Lan-chou line was built, the same mistake was not repeated. The Wei Ho had to be bridged six times. Although the bridges were not very large and only 10 or more meters high, still they were quite expensive.

7. Crossing Two Summits

After passing Lung-hsi, the line had to cross the first of two mountain range divides at an elevation 1,000 meters higher than T'ien-shui. The grade had to be limited to a rise of no more than 10 meters per kilometer. Hence it was necessary to extend the length of the alignment. After the first summit was passed, it was necessary to build a big bridge over the Hsien Ho, and go around by Chao-chia-kou, on the opposite side of the river, in order to regain elevation. When Ma-ho-chen was reached, the line had to make a complete loop, crossing over itself at a higher elevation. In this locality, it was necessary to cross the Hsien Ho three more times. Some bridges had to be built to accommodate curved stretches of track.

On this portion of the line, it was proposed to increase the grade from 1.2 percent to 2.2 percent, including the curve reduction ratio, and then use double-headers to haul the trains over this section. In this way the crossing of the river four times would be unnecessary with a consequent saving in construction time. Furthermore, if at a later date, a long tunnel were to be built, the grade could be made such that a single locomotive could haul the trains instead of a double-header.

Further along the route, another very high and broad range blocked the way. One attempt to tunnel it had failed. In the course of a few months, the ordinary bricks used for lining the tunnel disintegrated. To have continued along the same route would have meant loss and disaster. Accordingly a long tunnel was made at another location which not only reduced the number of high bridges to be built across deep gullies, but also shortened the distance by more than 10 kilometers.

8. Deep Gullies and High Bridges

The loess soil region is without forests; there are only bare hills separated by deep gullies with winding streams of brackish water. The line had to cross such gullies on bridges from 15 to 45 meters high at more than 100 places; the majority of the bridges were from 30-40 meters high. After rains, the water in these gullies was often 4 meters deep. The construction of these bridges was not a simple matter. If the piers and abutments had been built of concrete, it would have required tens of thousands of cubic meters of concrete for which suitable water, rock, and fuel, were not available locally. Hence it was decided to build structural steel bridge piers.

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9. The Ta-ying-liang Tunnel

On the railroads of North China, there are only a few tunnels, including the one more than 1,000 meters long at Kuan-kou in the Pa-ta-ling mountains. Although that tunnel and the V-shaped switchback are truly amazing, the new tunnel at Ta-ying-liang on the T'ien-shui--Lan-chou line is even more marvelous. It is several li long /1,980 meters long, according to the Sian Ch'un-chung Jih-pao of 1 October 1952/. Work on the Ta-ying-liang tunnel started 4 April 1951 with 200 aggressive construction corps troops working simultaneously from both ends of the tunnel. After penetrating to a depth of only 15 meters, they struck the hard red clay characteristic of Kansu. Using long steel rods this difficulty was solved and by the end of 1951, the tunnel was two thirds done. It was completed in July 1952.

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1. Location: China, Northwest China Administrative Area, Kansu, Ch'u-erh-ch'a Tunnel

Caption and Description: "Ch'u-erh-ch'a Tunnel on the T'ien-shui--Lan-chou Section of the Lung-Hai Railway." Color photograph shows the approach and entrance to the tunnel. It also shows the type of cutting of the approach, the single track leading into the tunnel, and train engine pushing one tank car and pulling another

Photograph Description: Size, 10 x 14 inches; good; slick paper

25X1 [redacted] Jen-min Hua-pao, Peiping, September 1952, front cover

25X1 [redacted]

2. Location: China, Northwest China Administrative Area, Kansu, Ch'u-erh-ch'a Tunnel

Caption and Description: "The Ch'u-erh-ch'a Tunnel, One of the Longest Tunnels in China, Was Completed a Year Ahead of Schedule." Photograph shows the inside of the tunnel

Photograph Description: Size, 4 x 5½ inches; good; slick paper

25X1 [redacted] Jen-min Hua-pao, Peiping, September 1952, page 18, top

25X1 [redacted]

3. Location: China, Northwest China Administrative Area, Kansu

Caption and Description: "View of the Railway Track and a Tunnel in the Ch'iu-chia'hsia Gorge." Photographs shows a stretch of the T'ien-shui--Lan-chou section of the Lung-Hai Railway, built along the Wei Ho in the Ch'iu-chia-hsia gorge, entering the mouth of a tunnel

Photograph Description: Size 6½ x 7 inches; good quality; slick paper



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25X1 [redacted] Jen-min Hua-pao, Peiping, September 1952, page 18, bottom
25X1 [redacted]

4. Location: China, Northwest China Administrative Area, Kansu, Tiao-chia-ch'uan Railway Bridge

Caption and Description: "The Highest Railway Bridge on the T'ien-shui--Lan-chou Section of the Lung-Hai Railway, the Tiao-chia-ch'uan Steel Bridge." Color photograph shows the type of construction of the highest steel trestle-type bridge on the T'ien-shui--Lan-chou section

Photograph Description: Size, 9 x 10 inches, good; slick paper

25X1 [redacted] Jen-min Hua-pao, Peiping, September 1952, page 19
25X1 [redacted]

5. Location: China, Northwest China Administrative Area, Kansu, Lung-Hai Railway

Caption and Description: "View of the T'ien-shui--Lan-chou Section Near Ch'e-chia'ch'uan." Color photograph shows the nature of the terrain.

Photograph Description: Size, $4\frac{1}{2}$ x 5 inches; good; slick paper

25X1 [redacted] Jen-min Hua-pao, Peiping, September 1952, page 20, top left
25X1 [redacted]

6. Location: China, Northwest China Administrative Area, Kansu, Lung-Hai Railway

Caption and Description: "Construction of Roadbed Near Shih-li-shan, the Last Section of the Line Between T'ien-shui and Lan-chou." Color photograph shows workmen using a compressed air drill on rocky terrain in the excavation of the roadbed

Photograph Description: Size, 5 x 5 inches; good; slick paper

25X1 [redacted] Jen-min Hua-pao, Peiping, September 1952, page 20, top left
25X1 [redacted]

7. Location: China, Northwest China Administrative Area, Kansu, Lung-Hai Railway

Caption and Description: "The Longest Railway Bridge on the T'ien-shui--Lan-chou Section, No 3 Bridge Over the Wei Ho." Color photograph shows a freight train going over concrete pillar-supported railway bridge across the Wei Ho

Photograph Description: Size, $7\frac{1}{2}$ x 11 inches; good; slick paper

25X1 [redacted] Jen-min Hua-pao, Peiping, September 1952, page 20, bottom
25X1 [redacted]



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8. Location: China, Northwest China Administrative Area, Kansu, Lung-Hai Railway

Caption and Description: "Entrance to the Ch'u-erh-ch'a Tunnel." Color photograph, taken from inside of the tunnel looking out, shows the lining of the tunnel, cut out section of the hill, an armed sentry, [probably a tunnel guard], and two workmen

Photograph Description: Size, $7\frac{1}{2}$ x 12 inches; good; slick paper

25X1 [redacted] Jen-min Hua pao, Peiping, September 1952, page 21

25X1 [redacted]

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